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Generation and application of a laser driven kT magnetic field

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kT magnetic field was generated by high energy laser in laboratory. A capacitor-coil target, which consists of two metallic disks connected by a coil, was applied to the magnetic field generation by irradiating with high energy GEKKO-XII laser. A peak magnetic flux density of 1 kT was detected at 850 μm from the coil center. Such a high magnetic field not only opens a new research frontier of plasma physics; but also provides a new test bed for condense matter, material, astro- and atomic and molecular physics.

1. Introduction

Laboratory generation of strong magnetic fields opens new frontiers in plasma and beam physics, astro-[1] and solar-physics[2], materials science[3], and atomic and molecular physics[4]. In fast-ignition laser fusion research, collimation of a relativistic electron beam by an axial magnetic field is a key scheme to increase the coupling efficiency between the laser and the core[5]. Magnetic field reconnection and collisionless shock generation1 in a plasma subject to a strong magnetic field are also current research objectives. A shaped kilotesla magnetic field has been long expected in laboratory. Here we report a kT magnetic field in mm scale, which is driven by the GEKKO-XII laser with maximum energy 1 kJ[6].

2. Magnetic field generation and measurement

The experimental setup is shown in Fig. 1. There are two disks on the capacitor-coil target. Several beams of GEKKO-XII laser were focused on the first disk through the hole on the second disk. Electrons drift from the focus point to the second disk along with the plasma expansion. There are positive and negative charge gathered on the two disks respectively, and thus, a large electrical potential is developed. This potential drives a current in the coil, and consequently a strong magnetic field is generated.

In the experiment, the incident laser energy ranging from 200 to 1000 J, with a pulse duration of 1.3 ns. The magnetic field flux density was measured by Faraday rotation. A fused silica cylinder was applied as the Faraday crystal, which is located 850 μm away from the coil center. By measuring the rotation angle θ, the magnetic field flux density can be calculated as:

$$H = \frac{\theta}{V \times L} \qquad (1)$$

where V is the Verdet constant of the fused silica and L is the length of the cylinder.

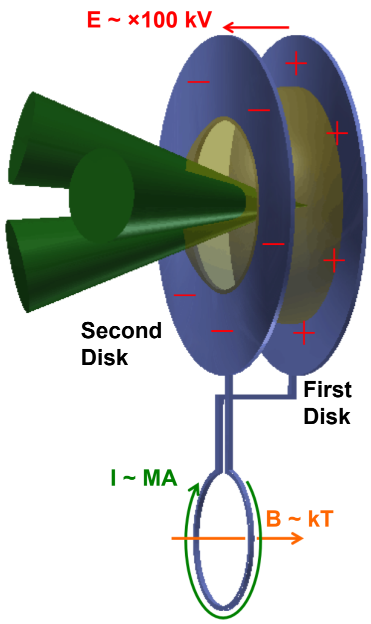

Fig. 1. Illustration of the Magnetic field generation.

3. Results

By varying the incident laser energy and focus spot size, the intensity is modified from 10^{14} to 10^{16} W/cm^2. The magnetic field flux density as a function of the intensity is shown in Fig. 2.

A general trend is the magnetic field increases along with increasing of laser intensity.

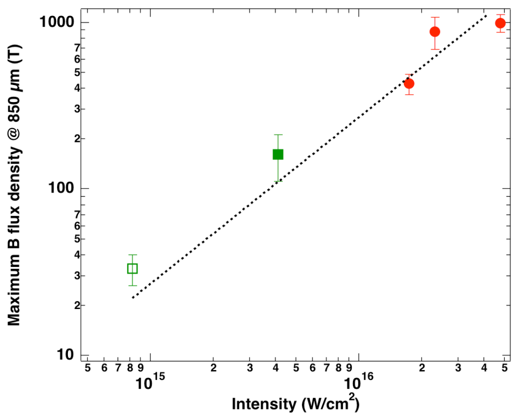

Fig. 2.The magnetic field flux density as a function of laser intensity.

4. Shape of the magnetic field

The shape of the magnetic field is strongly related to the shape of the coil. For example, 3 types of coils were simulated: 1. a full coil; 2. a practical coil with a gap; 3 a U-turn coil, as shown in Fig. 3(a), (b) and (c).

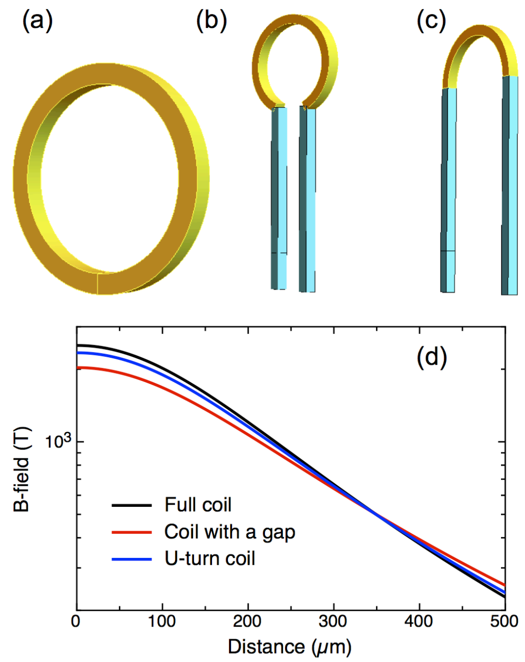

Fig. 3. The magnetic field of 3 types of coil. (a). a full coil; (b) a practical coil with a gap; (c). a U-turn coil.

The magnetic field flux density at the coil center along the axial direction is plotted in Fig. 3(d). The current is assumed to be 1 MA, which is a typical value achieved in our experiments. It can be seen: within 350 μm, the magnetic field of a full coil is stronger than the other 2 cases; while out of 350 μm, the magnetic field of a full coil is weaker. Generally, the magnetic field is more concentrated with smaller gap. It is possible to re-shape the magnetic field by modifying the gap space for different applications.

5. Applications

The magnetic field generated from the capacitor-coil targets has been applied to relativistic electron beam collimation in LULI-2000 laser facility and magneto-hydro-dynamics (MHD) studies on GEKKO-XII. The detail will be provided in the presentation.

Acknowledgments

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